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JUN 81 E V BONDAREV, A M GENIN, G I GURVICH

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USE OF A TWO-GAS ARTIFICIAL ATMOSPHERE
FOR MANNED SPACECRAFT

by

E. V. Bondarev, A. M. Genin, et al.

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(6) USE OF A TWO-GAS ARTIFICIAL ATMOSPHERE FOR MANNED SPACECRAFT,

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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

USE OF A TWO-GAS ARTIFICIAL ATMOSPHERE
FOR MANNED SPACECRAFT

E. V. Bondarev, A. M. Genin, G. I. Gurvich, M. D. Draguzya, V. A. Yegorov, Yu. N. Yeleshin, M. P. Yelinskiy, O. K. Yerykalova, Z. N. Parfenova, and V. V. Rassvetayev.

An artificial atmosphere is created and maintained in the cabins of space craft. Thus far, there is no consensus as to what type of medium this should be - one- or two-gas atmosphere.

One of the arguments in favor of using a multigas oxygen medium at a low barometric pressure (300–250 mm Hg) on the spacecraft has to do with a significant decrease in the probability of the cosmonauts developing decompression sickness as they leave the ship to venture out into open space in a spacesuit.

At the same time, there are drawbacks to a multigas atmosphere. An atmosphere consisting of pure oxygen can be the cause for the development of diffusion atelectases in lungs and disruption of barofunctions of the ENT organs and it increases the danger of fire.

The purpose of this study is to determine whether man can experience a decompression sickness when he changes from the nitrogen-oxygen atmosphere at high barometric pressure of 405 mm Hg to a one-gas oxygen medium at 170 mm Hg (to a certain extent, this simulates a suited cosmonaut going out into open space).

Conditions and Procedure for Conducting Experiments.

The tests were conducted in a pressure chamber on 100 test subjects (men in the age group from 19 to 21). All test subjects were examined medically prior to participating in these experiments. The studies were conducted in a pressure chamber equipped with oxygen devices operating on automatic pulmonary principle. Without preliminary desaturation the test subjects were elevated to an "altitude" of 5000 m (405 mm Hg) at a rate of 15–20 m/s; the time spent at this "alitude" was 10 h. The test subjects were breathing a nitrogen-oxygen mixture containing 45–47% of oxygen, and at the end of the 10-hour period at an altitude of 5000 m they were switched to pure oxygen. The next elevation was to 11000 m (170 mm Hg) at a rate of 25–30 m/s; they were kept at this "altitude" for 4 h. Temperature in the chamber was maintained between 22 and 27°. Before and after the experiments, the test subjects were placed into a therapeutic clinic for 24 h, where the medical personnel consisting of a therapist, neuropathologists, otorhinolaryngologist, and ophthalmologist examined them clinically. They examine the general state of health and also certain clinical and biochemical indices of blood and urine.

Twenty four hours before the experiments the test subjects were placed on a special ration, which corresponded to the requirements imposed on the diet of a flight crew for high-altitude flying.

Throughout the experiment, periodic recording was made of the heart rate, EKG, respiration rate, and pulmonary ventilation, also determined were the gas composition and alkaline reserve of blood.

The composition of the exhaled air and pulmonary ventilation were studied in the initial state (after the test subjects spent half an hour at rest before they were taken to an "altitude" of 5000 m) and at the end of their stay at the "altitudes" of 5000 and 11000 m. The exhaled air was collected in Douglas bags at 15-minute intervals and was analyzed in the Holden apparatus. The amount of the exhaled air was determined by means of a wet gas counter, GSB-400. The volume of pulmonary ventilation was adjusted to normal conditions.

To determine the blood content of oxygen, carbon dioxide, and alkaline reserve, the samples were taken from the ulnar vain, collected under vaseline oil on the "Earth" and at the end of their stay at the levels of 5000 and 11000 m. The gas composition of the blood was

analyzed by means of a monometric Van Slyke apparatus.

The following tests were used to study the psychological functions: to study the mental capacity - devision (in one's head) of four-digit numbers by 3; concentration - with the aid of the tables with Landolt's rings; and memory - immediate repetition of the two-digit numbers read by the examiner. The speed at which the processing of information was accomplished to light, sound, and tactile signals was determined.

Ten minutes after the pressure in the pressure chamber was reduced to 170 mm Hg, the test subjects were given a physical load - three sets of exercises lasting 5 min each: lifting 4-kilogram dumbbells (20—24 times a minute), stepping onto a step 0.25 m in height (32—36 times a minute), and second exercise with the dumbbells. The work performed in this period equalled to 4800—5200 kg.

The test assignments were performed by the subjects in intervals after resting from 30 to 60 min.

Results and Their Discussion.

Change in physiological indices. Immediately before the elevation to an "altitude" of 5000 m and during the elevation, the subjects exhibited a certain neuroemotional stress with the manifestation of an apprehensive reaction to the unusual conditions and the experimental situation. The heart rate increased by 20—30 beats, EKG remained without any visible changes, respiration rate increased by 5—6, and pulmonary ventilation - 2—3 l/min.

As the "altitude" of 5000 m was reached and the rest of the time under these conditions, the recorded indices of the physiological functions returned to the initial level and, in some cases, they were even below the initial values.

The subsequent pressure differential from 405 to 170 mm Hg, all of the subjects withstood without any visible physiological reactions.

After the physical load, the pulse rate rose to 130—164 beats a minute, respiration rate - 36—40 times a minute, and pulmonary ventilation - 28—36 l/min.

In the majority of cases, with the elevation to the "altitude" the values, which characterize pulmonary ventilation and which were adjusted to normal conditions, were lower than the inital readings.

However, the actual pulmonary ventilation both during the period spent at the "altitude" of 5000 m and, especially, at 11000 m was higher in all the subjects (Table 1).

The following changes were detected in the blood's gas composition: an increase in the oxygen content, a decrease in the carbon-dioxide content, and a decrease in alkaline reserve (both at 5000 m and at 11000 m). The changes in the content of O_2, CO_2, and alkaline reserve can be explained hypothetically by the increase in blood flow in the subcutaneous and intracutaneous vessels caused by the requirements of thermoregulation associated with an increase in the air temperature in the pressure chamber up to 26–27^{o} and, also, hyperventilation.

Results of clinical examination. During the examination following the pressure-chamber tests, none of the subjects had any specific complaints, which would have attested to the damage done to the nervous system. Some reported only a slight headache, noise in the ears, and decreased hearing, and also weakness and sleepiness, which, undoubtedly, was the result of the lack of sleep and fatigue, and also the consequence of the compression pressure differential, to which the test subjects were subjected before leaving the pressure chamber. The study of the neurological state has shown that some individuals developed new neorological symptoms or, if they had these symptoms before, they intensified. The relative frequency of the detected symptoms, before and after the tests, is shown in Table 2.

It can be seen from Table 2 that after the tests, some individuals developed symptoms of oral automatism, assymetry of deep and surface reflexes, and also pathological reflexes in feet, which attested to the ensuing deficiency of the pyramidal tracts. Pathological reflexes (Babinski's sign) developed in two individuals on both feet, and one had it only on one side (temporary Babinski's sign). As a rule, these symtoms were not permanent and were not observed upon the subsequent examination the following day. None developed any functional disturbances (neuropsychological activity, speech, movement, etc.). All the test subjects were virtually healthy after the pressure-chamber tests and were able to resume their usual tasks after a sufficient rest.

The therapist made note only of the fact that, after testing, some test subjects showed increased heart rate (P=0.01), increased minimum

Table 1

Volume of pulmonary ventilation and gas composition of the exhaled air, gas composition and alkaline reserve of blood in test subjects initially and at the end of the periods spent at 5000 and 11000 m.

Таблица 1

Объем легочной вентиляции и газовый состав выдыхаемого воздуха, газовый состав и резервная щелочность крови у испытуемых в исходном состоянии и в конце пребывания на высотах 5000 и 11 000 м

(f) Испытуемый	(a) Легочная вентиляция (в л/мин)					(b) CO_2 выдыхаемого воздуха (в %)			(c) O_2 выдыхаемого воздуха (в %)			(d) Газовый состав венозной крови (в об. %)						(e) Резервная щелочь		
		(g) на высоте 5000 м		(g) на высоте 11 000 м								O_2			CO_2					
	(k) исходная	(i) приведенная к нормальным условиям	(j) действительная	(i) приведенная к нормальным условиям	(j) действительная	(h) исходный	(g) на высоте 5000 м	(g) на высоте 11 000 м	(h) исходный	(g) на высоте 5000 м	(g) на высоте 11 000 м	(h) исходный	(g) на высоте 5000 м	(g) на высоте 11 000 м	(h) исходный	(g) на высоте 5000 м	(g) на высоте 11 000 м	(h) исходная	(h) на высоте 5000 м	(h) на высоте 11 000 м
Л.	—	—	—	—	—	—	—	—	—	—	—	8,6	13,3		49,0	38,1		43,7	26,9	—
А.	10,0	8,7	13,8	7,0	31,3	3,7	3,8	5,6	—	—	—	5,11	11,61	6,39	52,7	46,5	46,8	50,4	31,7	33,8
Р-ко	—	—	—	—	—	—	—	—	—	—	—	16,2	11,8	—	51,1	46,8		40,8	39,6	—
Ю.	9,1	7,2	13,6	5,5	21,6	3,6	6,0	7,2	17,3[1]	31,6	78,8	6,6	13,3	11,1	50,6	49,2	49,7	41,1	39,8	45,2
Ч.	—	—	—	—				—	—	—	—	7,2	17,0	17,7	41,6	47,1	45,5	40,3	27,6	46,6
Ф.	16,0	10,1	19,2	9,0	35,5	2,2	5,9	13,7	38,7	35,1	82,7	6,4	16,7	—	51,9	47,1		52,7	37,0	—
Т.	—	—	—	—	—	—	—	—	—	—	—	4,9	15,7	16,01	55,1	51,9	48,1	56,1	43,1	—
С-он	8,7	6,8	9,1	10,3	16,0	3,1	6,1	10,3	37,8	35,7	88,2	—	—	—	—	—	—	—	—	
З-в	—	—	—	—		—	—	—	—	—	—	12,8	15,1	11,8	47,1	46,8	39,8	37,6	36,1	41,0
С-ов	9,9	7,3	13,8	12,9	57,6	3,5	6,4	9,0	16,9[1]	33,9	88,2	6,41	—	—	52,5	—	—	47,0	—	—
С-ко	—	—	—	—	—	—	—		—	—	—	4,7	16,0	11,6	55,7	46,5	46,8	45,0	—	41,9
З-ч	10,6	6,9	13,3	4,5	20,1	3,1	6,3	13,7	38,7	33,9	80,0	2,7	13,8	13,3	50,8	43,9	41,1	43,2	38,3	39,2
С-в	—	—	—	—	—	—	—	—	—	—	—	12,8	16,2	15,7	48,1	44,7	43,1	45,0	43,2	39,2
М.	10,0	8,7	16,5	8,9	35,2	3,6	7,4	11,5	39,8	37,2	83,5	11,1	15,3	16,0	53,0	51,4	45,5	51,0	48,4	43,8
Р-в	—	—	—	—	—	—	—	—	—	—	—	9,1	—	8,1	50,0	—	50,0	37,0	—	41,7

[1] Кислородную маску к кислородному прибору не присоединяли.

[1] The oxygen mask was not connected to the oxygen device.

KEY: (a) Pulmonary ventilation (in l/min) (b) CO_2 in exhaled air (in %) (c) O_2 in exhaled air (in %) (d) Gas composition of venous blood (percent by volume) (e) Alkaline reserve (f) Test subject (g) at the "altitude" of (h) initial (i) adjusted to normal conditions (j) actual

arterial pressure (P=0.01 but the maximum arterial pressure was decreased (P=0.01). These changes bore a transient nature and they, apparently, should be viewed as a compensatory reaction to the effect of a set of unusual factors. No other deviations were observed.

The data of the otorhinolaryngologist and ophthalmologist did not

contain any complaints from the test subjects. No noticeable differences were observed from the initial data on the ENT and visual organs during an objective analysis.

Table 2

Comparative frequency of neurological symptoms before and after testing.

Symptoms	Frequency of Symptoms	
	before testing	after testing
Anisocoria	4	4
Nonunifirmity of lid slits	1	1
Asymmetry of nasolabial folds	2	3
Marinesco's sign	3	8
Khobotkov's sign	0	2
Lip reflex	0	2
Khvostek's sign	2	2
Anisoreflexia on hands	0	1
Asymmetry of abdominal reflexes	0	3
Absence of abdominal reflexes	0	1
Anisoreflexia on legs	0	2
Asymmetry of plantar reflexes	0	2
Pathological reflexes on feet	0	3
Nystagmus	0	1

Thus, the polyclinical examination of the test subjects shows that their 4-hour stay at the "altitude" of 11000 m, after a preliminary 10-hour desaturation from nitrogen at 5000 m, did not cause any serious disorders of the main organs and organism's systems. The deviations developed in some individuals were short-lived and disappeared on the following day (and most cases right after the experiment).

Results of the Laboratory Experiments

As a result of the experiment, 58% of the test subjects showed a tendency towards an increase in the amount of 17-oxycorticosteroids

in a 24-hour urine sample (M_1=4.86 mg; M_2=5.56 mg; t=2.4[1]), while it changed insignificantly in blood (M_2=12.49 mg; M_1=12.72 mg; t=07). This type of change in the metabolism of the corticosteroids attests to the increase in the clucocorticoid activity of the adrenal cortex.

The amount of 17-ketosteroids in a 24-hour urine was clearly increased in 60% of the cases (M_1=12.83 mg; M_2=15.91 mg; t=3.0), which also indicates an active function of the adrenal cortex.

We were unable to find any direct indications in our and foreign literature available to us, which connected the changes in the function of the adrenal cortex with high-altitude decompression. However, there are data on the change in the activity of the adrenal cortex when man and animals are subjected to a number of unusual stress factors.

One can assume that in the course of the experiment, the test subjects experienced an emotional reaction and tension (stress) due to an unusual situation (awaiting decompression, relative hypodynamia, staying awake at night, prolonged interval between feeding, etc.). This results in an increased functional activity of the hypothalmo-hypophysial-adrenal system.

In our experiments (judging by the result of change in the metabolism of corticosteroids), the reaction to the stress situation on the part of the hypothalmus-pituitary-adrenal system was moderate.

The test subjects showed a tendency towards an increase in the total numner of leukocytes (M_1=6367, M_2=7003 per 1 mm^3) due to the segmented neutrophils, whereas the relative number of lymphocytes was clearly decreased. This type of change in the "white" blood and leukogram can be explained by an increase in the glucocorticoid activity of the adrenal cortex.

The analysis of the results permits us to assume that these changes should be viewed as a normal response of the body to a stress situation.

Results of the psychophysiological examination. The comparison of the base-line data with the results of the studies at the end of 14 h spent by the test subjects under the conditions of reduced barometric pressure (when an organism has a sufficient amount of oxygen) has revealed that there were no, statistically reliable, changes. Thus, in

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[1] M_1 is an average index before the experiment, M_2 is the same after the experiment.

the case of the test "division of numbers by 3", before the elevation, the average time of solution was 6.4–8 s with an average number of errors at 2.5–2.7 out of 12 problems; after their stay at an "altitude", these indices were 6–6.5 s and 1.5–1.7 errors. The average operating capacity using the Landolt's rings technique was 1.14–1.54 bit/s before the elevation and 1.16–1.33 bit/s after. Before being elevated to an "altitude", test subjects could remember 3.8–4.7 numerals on the average, at the end of their stay in the pressure chamber - 4.7–6. The tentency towards a certain improvement in the results is apparently explained by a certain emotional lift associated with the termination of a relatively prolonged experiment.

The information processing rate remained (with some fluctuations) at the same level throughout the experiment: for light signals - 3.3 bit/s on the average initially and 3.54 bit/s at the end of the experiment; for sound signals - 3.15 and 2.78 bit/s, respectively; and for tactile signals - 3.28 and 3.2 bit/s.

Thus, the experimental conditions did not produce significant changes in the mental capacity, concentration, and memory of the test subjects, and also in the rate of information processing to signals of varied modality.

The noted isolated deviations in the organism's functions of the test subjects were caused by the unusual conditions of the experiment, its duration, relative hypodynamia, and also by the ensuing fatigue.

The materials obtained by us make it possible to consider the two-gas atmosphere used by us for the spacecraft, which a suited cosmonaut can leave to venture out into an open space, as acceptable.

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